Use Of The P-2000 With Small Diameter Glass

Puller Bars

The normal puller bars of the P-2000 will not clamp glass that is much smaller than 0.5 mm in diameter. At your request we installed special puller bars with a very shallow groove that can clamp glass as small as 0.125 mm in diameter.

Optical Adjustments

The optical system of the P-2000 was designed to evenly heat all sides of 1 mm diameter glass. Even heating is not as essential for glass rod or fiber less than 0.2 mm in diameter, since heat can conduct fairly quickly over such small distances. Your puller was first set-up and checked with 1 mm diameter tubing, and some of the programs entered were for use with that combination of glass and adjustment. Once we established that the unit was operating correctly, it was readjusted for 0.125 mm diameter fiber.

Small diameter glass obviously presents a small target for the laser beam, so that most of the beam misses the glass and is reflected off the cylindrical "retro" mirror. The reflected beam converges toward a rough line of focus that is parallel to the glass. The ideal optical adjustment places the laser beam, the glass and the line of focus in the same plane. The glass should be slightly towards the "retro" mirror from the line of focus. If the glass is too close to the line of focus the heating becomes very uneven and much too sensitive to the exact position of the glass. If you plan to switch to larger glass on a long term basis, you may wish to optimize the optical adjustments for that glass.

The laser beam can easily be aimed at the glass using thermal paper as outlined in the manual. I suggest that a DEL value of 40 be used instead of the value of 100 in the manual.

The vertical position of the cylindrical "retro" mirror should be adequate as set by Sutter. This was done by adjusting the vertical position to find the position that allowed the fiber to melt at the lowest possible heat value. This should correspond to zero on the mirror positioner scale.

Should you feel that this adjustment is not correct, it might be

wise to contact Sutter for advice before making any changes. If you do need to repeat this process, enter the following test program:
HEAT=350 FIL=0 VEL=20 DEL=124 PUL=150

Load a sample of your glass and press pull. If the glass melts, the laser power light should go out and the glass may separate. If the glass does not melt within 4 seconds, press stop, adjust the "retro" position slightly, and try again. Any vertical position that allows the glass to melt is close to the proper adjustment. To further tune the position, replace the glass, drop the HEAT by 25 and continue. The "retro" mirror should require only a slight adjustment. If the glass does not melt at any position, try a higher starting heat. Newer units display the heating time after the glass separates. You could adjust to the position that gives the smallest time to melt.

One point of confusion has occasionally arisen with the retro mirror adjustment. The laser beam is scanned into position with the power on. If very high values of HEAT are used it is possible for the beam to melt the glass as it scans into place. If the glass, the line of focus, and the scan are not in parallel planes, you may place the "retro" mirror in a position that will melt the glass as the beam scans in at a lower HEAT value than that which will melt the glass when the beam is in the normal heating potion. If this occurs you will find that the heating time reported by the puller will stay very low for all heats that melt the glass, since the glass is actually melted before the timing of the normal heating interval starts. This should not be a problem if the mirror adjustment is correct. You may be concerned about the mirror adjustment if with a HEAT value over 400 is required to melt fiber with FIL 0.

Program Parameters
The basics of selecting program parameters are covered in the manual. Here is a typical program for 125 µm diameter fused silica fiber:
HEAT=325 FIL=0 VEL=20 DEL=125 PUL=125

The HEAT will need to be adjusted to melt the glass in 0.1 to .4 seconds. The heating time is displayed after the pull is complete. For tips as small as 40 nanometers in diameter, the heat should be sufficient to melt the glass in .12 to .16 seconds.

VEL and DEL also affect the heat content of the glass. Increasing VEL causes the laser to stay on longer after the glass begins to soften and it will delay the start of the hard pull as well. The normal range for the VEL value is 15 to 30 for 125 μm glass. If the value is too low, the glass may not separate or may break at a large diameter during the hard pull. If the value is too high, the glass may separate before the criterion velocity is reached. The later case can be identified by the following logic: If the tip separates before the hard pull turns on, the resultant tip will not depend on the PULL value entered.

Decreasing DEL will increase the temperature of the glass at the start of the hard pull. If values less than 120 are used, the laser will probably remain on until the tips have formed, so the most useful range for DEL is 120 to 130 when small diameter glass is used.

If the glass breaks at a large diameter, the glass was probably not hot enough when the hard pull turned on. If the HEAT level is too high and the velocity is low, the outer layer of the glass can become much hotter than the core. If this happens, the hard pull can break the core and then draw the outer layer out past the end of the broken core. The outer layer will then usually appear as a "bee stinger" that may even be bent back on itself.

PUL affects the taper length and tip diameter in a fairly simple manner. The higher the pull, the longer and finer the tip. The most useful PUL values are in the range of 75 to 200. For fused silica of 125 μm diameter, a value of 125 is about right for 100 nanometer tips, and 150 will allow tips of about 40 nanometers to be formed. The best values for the other parameters may change a bit with changes in PUL.

FIL allows you to control the distribution of the laser beam along the length of the glass. Using FIL 0 causes the laser beam to simply point at the glass, so the beam profile determines the distribution of power along the glass. Since the nominal beam diameter of 3 mm is many times the diameter of small glass, little of the heat applied by the center of the beam is lost to conduction along the glass to the unheated portions of the glass. FIL 0 is able to produce very small tips with a short taper length. FIL 2 or FIL 3 could be used to produce a longer taper. Consult the manual for potential problems with small glass.

P-2000 pullers that were adjusted for small diameter glass normally had a reduced weight solenoid plunger assembly. This provided a reduced force for the weak pull produced by gravity and a reduced inertia for the hard pull. This modification did not seem to produce any real improvement in performance, but it may shift the effective VEL value. Your P-2000 was shipped with the standard assembly. Please keep this in mind when seeking advice from Sutter Instrument Company or from other users of the P-2000.

Loading Small Diameter Glass

Glass tubing or fiber with a diameter of less than 250 µm will often be very flexible, which makes it more difficult to load than the stiff larger diameter material. To aid in loading, we have cut a slit in the aluminum enclosure that covers the "retro" mirror so that the glass can be dropped in rather than pushed through this enclosure.

The glass to be loaded must be clean and free of any coatings or jacket in the region that is to be heated. Coatings that are left on the glass will cover the "retro" mirror with debris and will prevent proper heating of the glass. Plastic jackets, such as used on fiber optics, must be completely removed in the region to be heated. This may be done with a mechanical fiber optics stripper, chemical treatment, or heat. Make sure any residue is cleaned off. The jacket on 3M optical fiber FS-SN-3224 strips very well with the "No-Nik" fiber optics stripper made by the Clauss company.

A piece of glass 7 cm in length is sufficient to allow both ends of the glass to be properly clamped, but loading the glass is a little easier if the piece is at least 12 cm in length. Slide the prepared glass into the slot in the enclosure. The most difficult task is getting the glass clamped in the puller bar grooves. It is best to first use a finger of one hand to locate one end of the glass in the groove beyond the finger cut-out in the puller bar while pulling lightly on the glass from the other side of the enclosure with the other hand. While holding the glass in this position, tighten the clamp with the other fingers of the first hand. Inspect the fiber to be sure that it is in the groove. Now use the first hand to draw the puller bars together, after releasing the flat springs that catch the puller bars. Use a

finger of the second hand to move the glass into the groove of the other puller bar, and tighten the clamp.

If the glass is about 12 cm in length, both ends should stay in place in the groove beyond the finger cut-out once the clamps have been tightened. If the glass is not in the groove under the clamp, it will usually cause the glass beyond the cut-out to pop out of the groove. If the length of glass beyond the clamp is more than a few cm, it may drop out of the unclamped portion of the groove once you remove your hand, but this is of no concern if the glass under the clamp is in the groove.

If the glass is extended in length on only one side, it is best to clamp the long side first. You can have the puller bar away from the mirror for better visibility and you have more free use of your hands. If the second end clamped extends just beyond the finger cut-out, the free end of that fiber resting in the groove is a good indicator of proper clamping.

If the bare glass is less than 200 μm in diameter, it may become difficult to clamp tightly. If possible, do not remove the jacket from the region of glass that is to be clamped.

The final test for proper clamping of the glass is a proper pull. You should find that the time to melt provides a good indication of proper preparation and clamping of the glass. If the time to melt is much longer than usual for given program, check the glass position before you remove the glass from the clamps.